Near-Earth Tracking and Data System Support for the Pioneer Venus 1978 Missions

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This article reports on the support provided by the Near-Earth Tracking and Data System (NETDS) for the Pioneer Venus 1978 Missions.

I. Introduction

The Near-Earth Phase Network for the Pioneer Venus Missions was composed of selected resources of Kennedy Space Center (Central Instrumentation Facility, Hangar AE Telemetry Laboratory and Communications), the Eastern Test Range (Range Instrumentation Stations, Real-Time Computer System, and Communications), 4950th Aerospace Test Wing (Advance Range Instrumentation Aircraft – ARIA), Goddard Space Flight Center (Spaceflight Tracking and Data Network – STDN), Deep Space Network (until initial DSN two-way acquisition), and NASA Communications Network (NASCOM).

A small group of JPL Eastern Test Range (ETR) Station personnel, headed by the Pioneer Venus NETDS Coordinator, operated under the guidance and direction of the JPL Pioneer Venus TDS Manager. The group participated in gathering requirements for near-Earth phase tracking and data support and monitored the levying of those requirements upon responsible implementing agencies via the appropriate documentation systems. The group monitored the planning and implementing efforts by such agencies and provided appropriate reporting to the TDS Manager to assure that all essential requirements were satisfied. This group also provided operational coordination between the Near-Earth Phase Network and the Project during launch operations.

II. Mission Planning

The Pioneer Venus Orbiter Mission was particularly difficult to plan for because of the wide variation in launch trajectories as indicated in Figs. 1 and 2. Geometric launch azimuths from 39 to 108 deg were considered with three basic configurations being selected. May 20 through June 3 had launch azimuths between 93 and 108 deg with Ascension Island and two or three Advanced Range Instrumentation Aircraft (ARIA) planned for the second Centaur Burn through spacecraft separation support interval. June 4 and June 5 were planned with 80-deg launch azimuths and four ARIA supporting from Africa. June 6 through June 10 launch data were planned using 60-deg launch azimuths and TDS downrange support from Wallops Island, Madrid, and four ARIA staging from Spain.

Two other factors had a major impact on the trajectories selected to enhance TDS support on the early launch days. The first was to have a long enough tracking interval from Ascension to send one command to the spacecraft after separation. The other was to have at least a two-hour view from Canberra (initial DSN acquisition station) to accomplish planned near-Earth science sequences. The major Near-Earth Phase Network resource problem regarding support of these varied trajectories was the scheduling of enough ARIA aircraft and moving them between staging bases on consecutive days.

The Multiprobe launch opportunity extended from August 7 through September 3. All launches were in the 93-to-108-deg flight azimuth sector. Geometrical requirements placed most of the Centaur second burn and Centaur/spacecraft separation events well beyond the Ascension Island tracking capabilities. Figure 3 illustrates the Earth tracks for selected Multiprobe launch days.

Again the major Near-Earth Phase Network resource problem with supporting the Multiprobe launch was scheduling enough ARIA. Four ARIA were scheduled and the trajectories designed such that the two downrange aircraft could fly far enough down-range from Ascension to acquire the last portion of the near-Earth TDS data interval.

The planning for both missions had one additional complication in that the spacecraft antenna pattern was such that the ARIA could not track a 60-deg cone at the rear of the spacecraft. This, in most cases, is what caused ARIAs 3 and 4 to be scheduled.

III. Implementation and Configuration

The ETR radars at Merritt Island, Patrick Air Force Base, Cape Canaveral, Grand Turk, Antigua, and Ascension were configured to transmit high-speed metric data to the Real Time Computer System (RTCS) at the Cape for both missions. The STDN Bermuda radar site was also configured to provide high-speed metric data to the RTCS on both missions.

The ETR RTCS was configured to process the metric data and compute (in real-time) JPL orbital elements, standard orbital parameter messages, acquisition data for selected NETDS stations and I-matrices. The Kennedy Space Center Central Instrumentation Facility was configured to process the real-time Centaur telemetry data and to provide Centaur state vector parameters to the RTCS for use by the RTCS in computing the Centaur transfer and postdeflection orbits.

Stations that were configured to support the launch vehicles and spacecraft telemetry links were Merritt Island, TEL-IV at ETR, Grand Bahama Island, Bermuda, Grand Turk, Antigua, Ascension (both ETR and STDN sites), and two to four ARIA. Also, the Wallops Flight Center and the STDN Madrid telemetry sites were configured to support a 60 degree launch azimuth.

For spacecraft real-time retransmission, all sites with the exception of Wallops Flight Center, Grand Turk, and the ETR Ascension site were configured.

MIL 71 received real-time spacecraft telemetry data from STDN stations, ETR stations, and ARIAs via 203 and 202D modems, as applicable. The MIL 71 Automatic Selection Unit source-selected one data stream for processing and reformatting into high-speed data blocks. These high-speed data blocks were transmitted to the DSN Network Operations Control Center at JPL and to the Pioneer Mission Operations Control Center at Ames Research Center. Spacecraft data were also provided by hard line and high-speed data line from MIL 71/MIL to the Spacecraft System Test Complex at the Cape.

Real-time retransmission of the launch vehicle telemetry data to Kennedy Space Center was from the same sites as indicated for spacecraft telemetry data. One additional telemetry site was configured for launch vehicle telemetry data only. This was the Orroral Valley site in Australia.

IV. Prelaunch Testing

The TDS Near-Earth Phase Test Plan identified and defined the planned prelaunch testing required to verify the readiness of the NETDS to participate in and support the Pioneer Venus 1978 Project test, training, and readiness program. It outlined support configurations and developed criteria and schedules for those prelaunch tests. The tests described therein preceded NETDS participation in the major readiness demonstration tests, i.e., the Mission Operations System and Operational Readiness Tests.

The test plan included a series of six spacecraft telemetry tests which were designed to (1) demonstrate the performance of MIL 71, and (2) demonstrate the performance of the STDN and ETR networks and of the ARIA's. All were successfully performed prior to the Orbiter launch. Applicable tests were repeated prior to the Multiprobe launch.

The Atlas-Centaur telemetry system was standard and had been flown prior to the Orbiter mission. The principal test efforts related to the real-time retransmission systems. The STDN 56 kb/s system was implemented and tested for the Orbiter mission. The ARIA 2.4-kb/s system containing Centaur DCU guidance parameters was implemented and tested for the Multiprobe mission. These systems were successfully demonstrated during the respective operations readiness tests.

A series of three tests were designed to demonstrate the performance of the ETR RTCS. An acquisition predicts test was conducted to verify the format and content of the RTCS-committed DSN predicts. A Venus B-Plane Mapping Test was conducted to determine the accuracy of the RTCS mapping program output parameters as compared to JPL mapping program output parameters. Both these tests were readily performed and the computations were validated. The third test was to validate the ETR RTCS-developed software change to process the new DSN high-speed metric data format. The test demonstrated that the RTCS was not able to consistently process this data. Evaluation indicated that the cost would be high to develop this capability, and the requirement for processing this data was subsequently dropped by the Project.

Various elements of the NETDS supported the Orbiter and Multiprobe prelaunch Mission Operations System and operational readiness tests as requested by the Project. Full participation in one operational readiness test prior to each launch was provided by all NETDS agencies. All Mission Operations System and operational readiness tests were successfully supported by the NETDS.

V. Orbiter Launch Support

The countdown for the Orbiter launch was reasonably smooth. One significant problem was a 24-min outage of the high-speed data flow from MIL 71 to the Project Mission Operations Control Center. This outage occurred just at the time scheduled for the spacecraft to read out the launch command sequence that had been stored by the Hughes equipment at the Cape for validation by Project personnel at the Control Center. The duration of the outage was extended, in part, by the use of a 33-bit error detector instead of a 22-bit error detector at the West Coast Switching Center. Fortunately, the Project was able to carry out the validation using the Hughes Cape equipment. The spacecraft activities proceeded such that it was possible later in the countdown to read out the command sequence at the Project Mission Operations Control Center after the circuit was restored.

Thunderstorms threatened the planned test support positions for the ARIAs. Alternate test site positions and look angles were selected and provided to the aircraft by teletype and by voice. However, it was not necessary to change to the alternate test site positions.

Data flow checks with NETDS stations and ARIAs were performed satisfactorily. Due to the lack of MARISAT availability, no spacecraft data flow was conducted by the ARIA's.

The Orbiter was launched at the opening of the launch window on May 20, 1978, at 1313 GMT. The launch vehicle performance and spacecraft injection were very nominal. The required spacecraft first midcourse correction, delayed from the planned date of launch plus seven days, was 3.193 m/s on the twelfth day.

All NETDS stations supported their respective data intervals essentially as planned. Major inflight (Mark) events through Mark 13, "Start Centaur Blowdown," were reported in real-time. The final event, Mark 14, "End Centaur Blowdown," occurred while out of view of NETDS stations. All Mark events received were within the nominal limits, with spacecraft separation occurring 4.4 seconds earlier than predicted.

Real-time spacecraft telemetry data from the Ascension STDN site were processed and displayed at the Project Mission Operations Control Center at Ames Research Center and at the Spacecraft System Test Complex at Building AO at Cape Canaveral Air Force Station. The data at Building AO indicated that the spacecraft was normal, but the data at the Control Center indicated that a tremendous number of spacecraft problems existed. This ambiguity in the spacecraft status caused the Project to elect not to send the spacecraft command via Ascension to start the science sequence. The problem was subsequently identified as a hardware problem at the Control Center, in which a bit error detector improperly reflagged bad data blocks as good.

The real-time computations (orbital elements, Inter-Net Predicts, Inter-Center Vectors, I-matrix, and planetary mapping) performed by the ETR RTCS were valid and delivered on time. Local and NASCOM long line voice and data communications were excellent. NETDS performance was essentially flawless, with almost all of the supporting stations providing more coverage than expected.

The expected vs actual radar coverage for the uprange stations is provided in Fig. 4. The two Ascension radars also provided more coverage than predicted. One radar provided actual coverage from 20 minutes 33 seconds to 28 minutes 18 seconds. The other provided 23s less coverage. The spacecraft and launch vehicle expected vs actual coverage for the stations is provided in Figs. 5 and 6.

The MIL 71 site transmitted 116% of the planned real-time spacecraft data to JPL and the Ames Project Mission Operations Control Center. Only 16s of nonplanned data dropouts occurred.

VI. Multiprobe Launch Support

The countdown for the Multiprobe mission went well except for a few communications problems. At about launch minus 190 min, the spacecraft telemetry data circuit between TEL-IV and MIL 71 failed. This circuit was the one which provided spacecraft data as received by TEL-IV backing up MIL during the early phase of flight and the circuit over which ARIA spacecraft data were to be transmitted through TEL-IV to MIL 71. After about 45 min of troubleshooting, a switch was made to an alternate circuit which was used through launch. At about 15 min after the switch, a frame module at KSC was replaced and the original circuit was made good.

At about launch minus 45 min, one data circuit between the Cape and Bermuda went down. The STDN Network Operations Manager requested that one of two Bermuda 7.2-kb/s circuits be released from real-time launch vehicle telemetry support for Launch Trajectory Acquisition System data to Bermuda. The circuit for launch vehicle Format B was released. The circuit that went down was made good prior to launch.

The extreme operating range of ARIAs 2 and 4, the takeoff order of all four ARIAs, and the prelaunch functions of the ground stations resulted in a minimal time period during which data flow checks with the ARIAs could be conducted. The available time was depleted by a variety of unexpected problems. One aircraft (ARIA 4) radiated for a while at too high a power level, which saturated the satellite and resulted in unfounded suspicions of interference by unauthorized users. Another aircraft (ARIA 1) had a defective summing amplifier which invalidated the launch vehicle telemetry portion of the combined launch vehicle and spacecraft data through the satellite. Good launch vehicle data leaving ARIA 2 arrived at Bldg AE via the HF path, but for an undetermined reason, did not do so via the satellite path. Delays incidental to the above precluded any opportunity to attempt a data flow check with the fourth aircraft (ARIA 3).

Based on the extent and success of the prelaunch data flow checks, it was decided that ARIAs 1 and 4 would be prime for real-time retransmission for launch.

The Multiprobe was launched at the opening of the launch window on the second day of the launch opportunity, August 8, at 7:33 GMT. The first day was missed due to insufficient liquid helium needed for prelaunch cooling of the Centaur engines being available at KSC. The launch vehicle performance and spacecraft injection were very nominal. The actual midcourse correction was 1.93 m/s at launch plus seven days.

All NETDS stations supported their respective data intervals essentially as planned. Major inflight (Mark) events through Mark 11, "Centaur/Spacecraft Separation," were reported in real-time. Mark 12, "Start Centaur Deflection," occurred within ARIA's view, but the aircraft were not equipped to make the real-time readout. Mark 13, "Start Centaur Blowdown," and Mark 14, "End Centaur Blowdown," occurred while out of view of NETDS stations.

All mandatory data intervals were supported. ARIAs tracked the spacecraft well past predicted coverage. ARIA 4's early loss of launch vehicle data was covered by the backup ARIA 2 (recorded only), justifying the commitment of ARIA backup resources.

MARISAT A support was excellent. Real-time spacecraft telemetry data relayed through the MARISAT link enabled the PMOCC to verify spacecraft spinup, a significant bonus that had not been entirely expected. The real-time computations (orbital elements, Inter-Net Predicts, and planetary mapping) performed by the ETR RTCS were valid and delivered on time. Local and NASCOM long-line voice and data communications were excellent, as was the overall support by the near-Earth trajectory and data system.

The radar expected vs actual coverage for the uprange stations is provided in Fig. 7. The two Ascension radars provided slightly more data than predicted. The TPQ-18 radar provided data from 20 min 41 s to 24 min 50 s, and the 12.15 radar provided data from 21 min 4 s to 26 min 25 s.

The spacecraft and launch vehicle expected vs actual coverage for the Near-Earth Phase Network stations is provided in Figs. 8 and 9.

The MIL 71 site transmitted 102.8% of the planned real-time spacecraft data to JPL and the Ames PMOCC during the interval, launch through Antigua loss of signal. There were an unusually high number of switches (15) by the Automatic Switching Unit between incoming data sources. All but 32 s of the planned data was provided, however. The MIL 71 site transmitted 12.5 min from Ascension and the ARIA. Most of the additional data were provided by longer than planned coverage from the ARIA, which fortunately allowed Ames Research Center to observe spacecraft spinup.

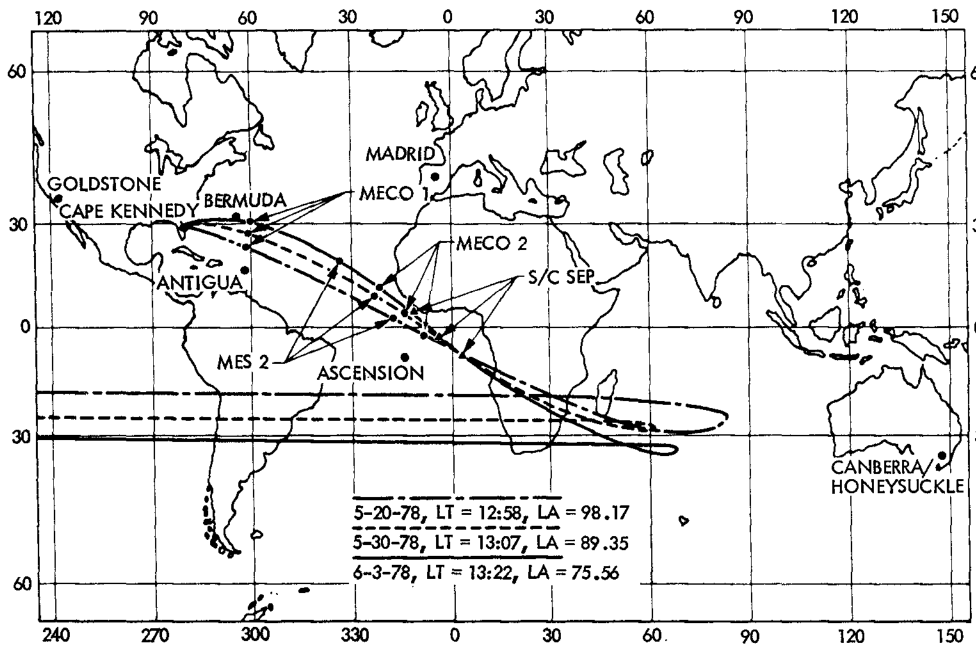

Fig. 1. Earth tracks for a Pioneer Venus Orbiter launch on May 20, May 30, and June 3, 1978

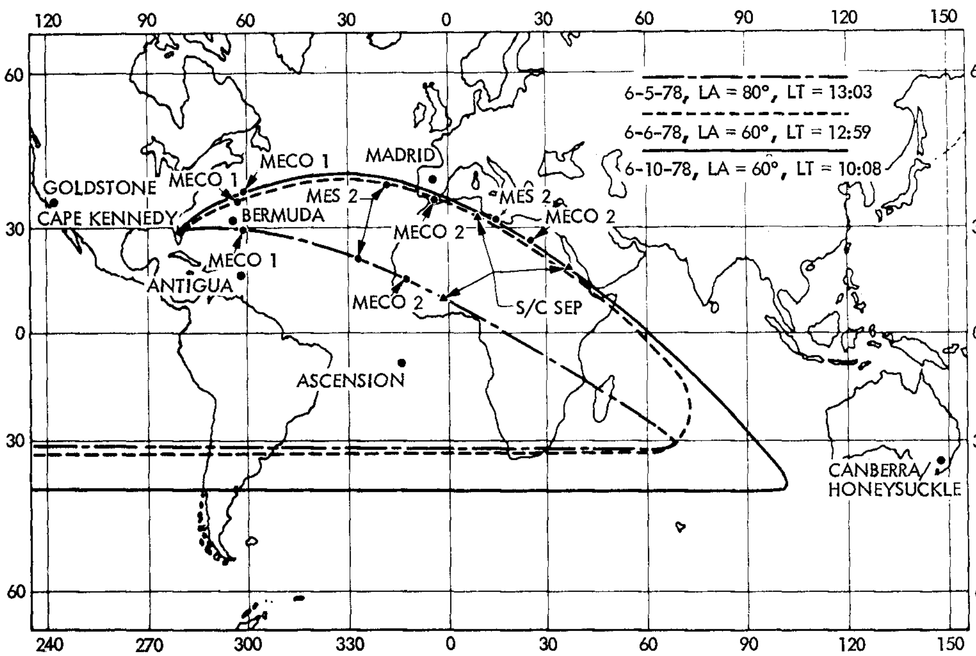

Fig. 2. Earth tracks for a Pioneer Venus Orbiter launch on June 5, June 6, and June 10, 1978

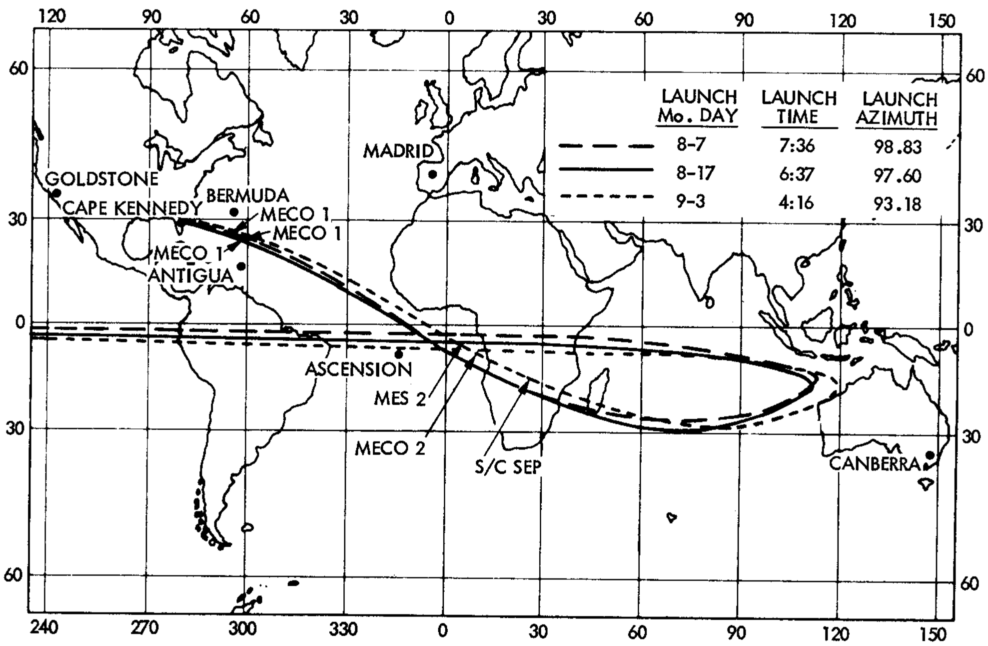

Fig. 3. Earth tracks for a Pioneer Venus Multiprobe launch

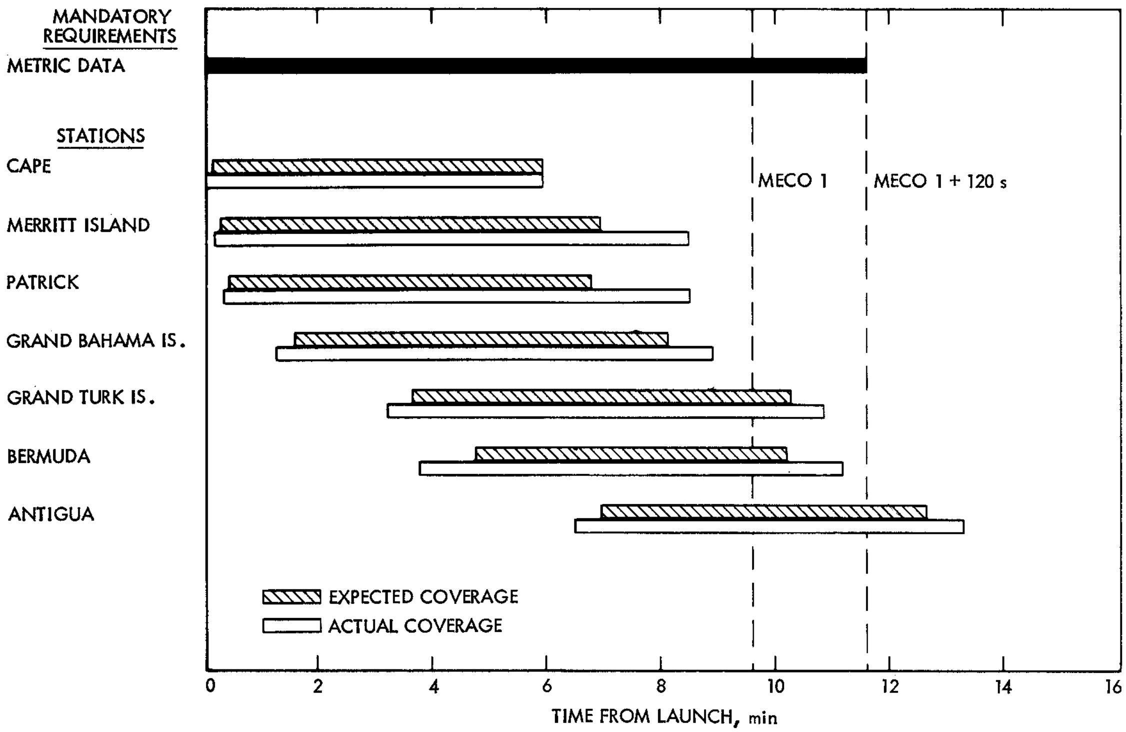

Fig. 4. Radar coverage for Pioneer Venus 78 Orbiter launch

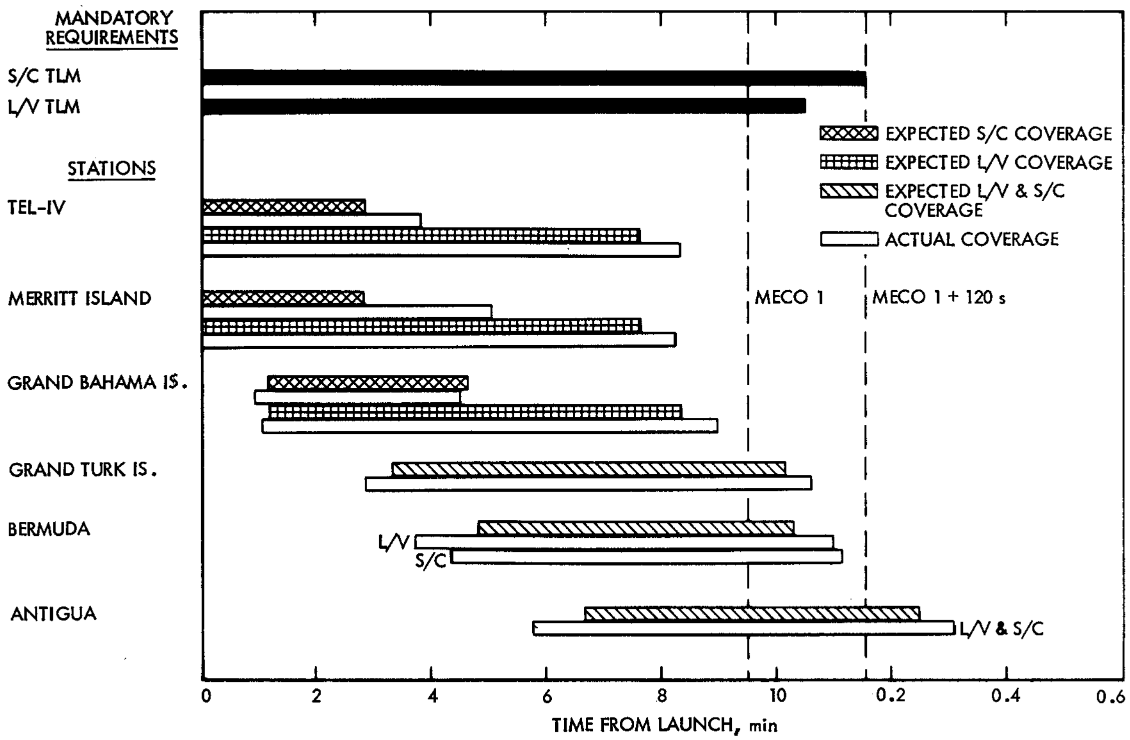

Fig. 5. Launch vehicle and spacecraft coverage for Pioneer Venus 78 Orbiter launch

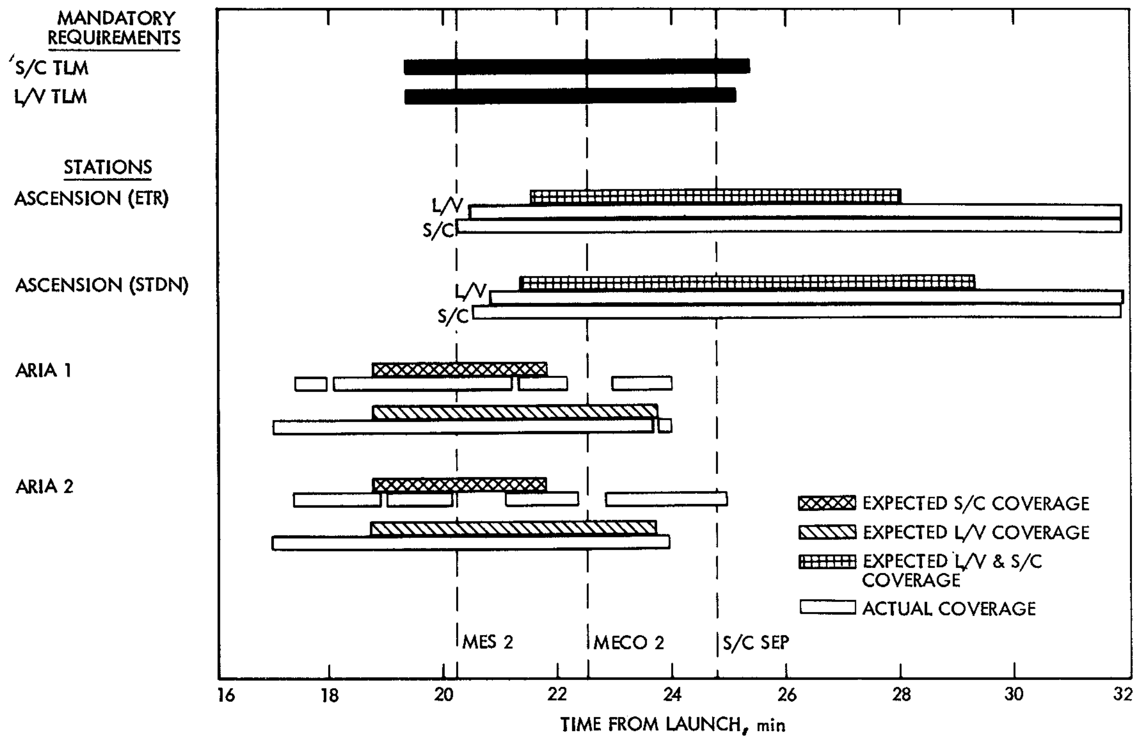

Fig. 6. Launch vehicle and spacecraft coverage for Pioneer Venus 78 Orbiter launch

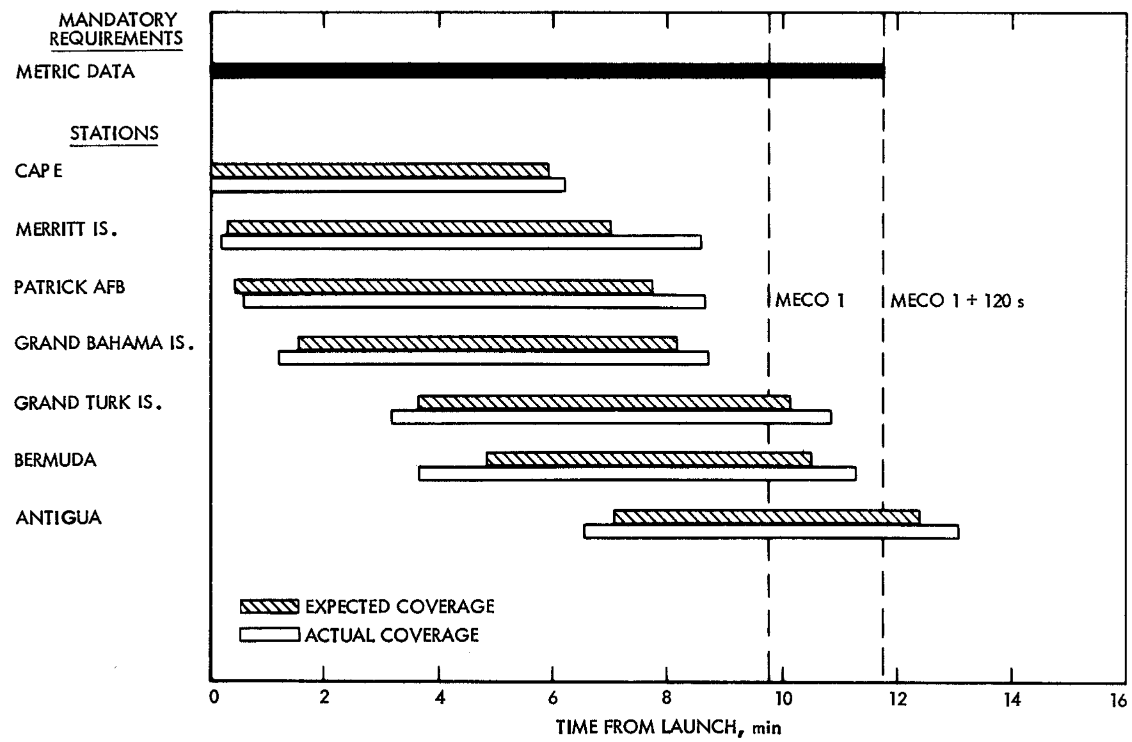

Fig. 7. Radar coverage for Pioneer Venus 78 Multiprobe launch

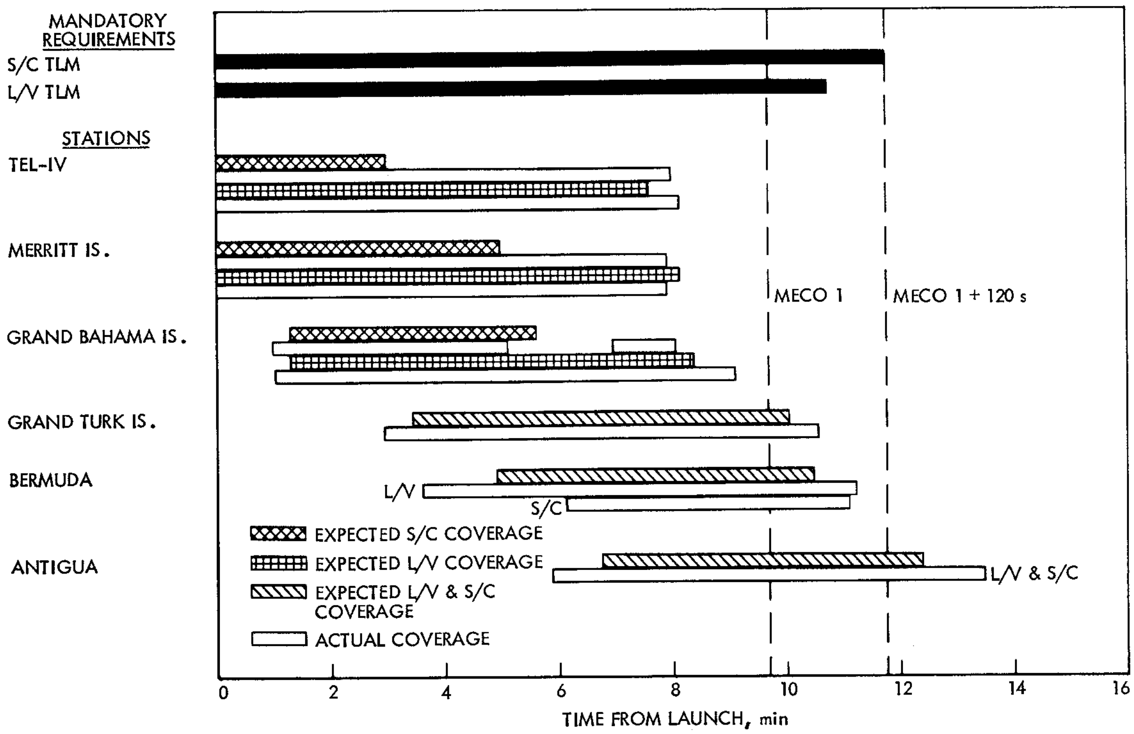

Fig. 8. Launch vehicle and spacecraft coverage for Pioneer Venus 78 Multiprobe launch

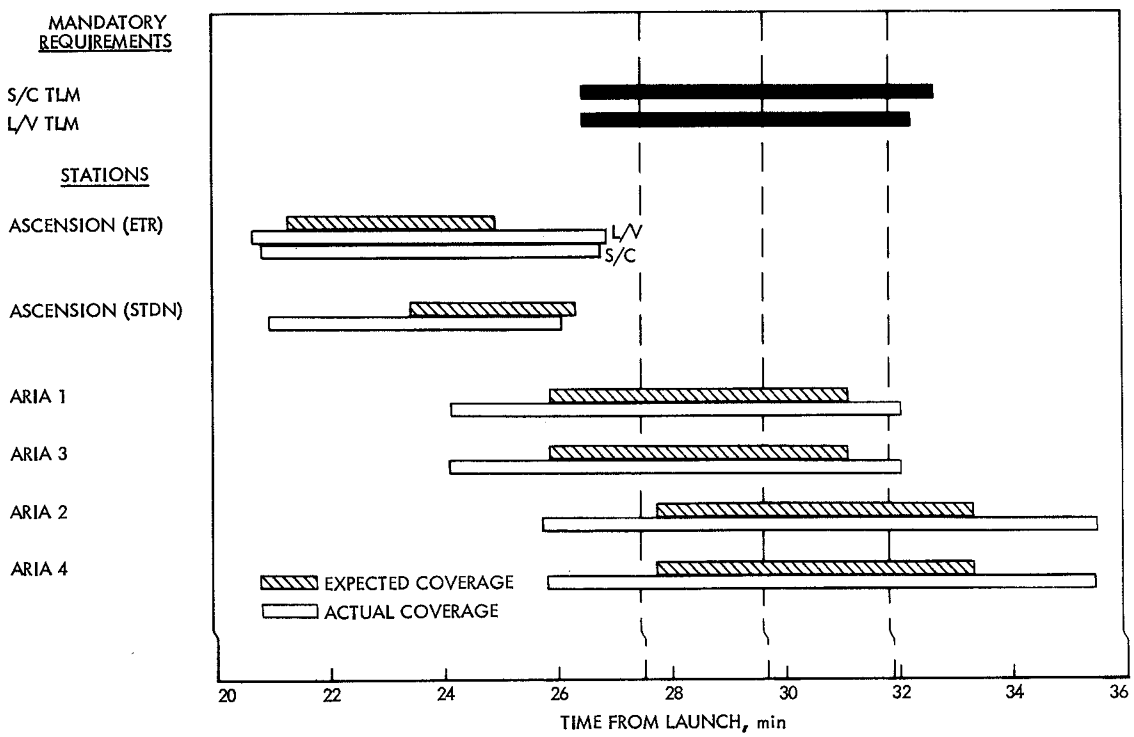

Fig. 9. Launch vehicle and spacecraft coverage for Pioneer Venus 78 Multiprobe launch